Summary of SHRP Research and Economic Benefits of

ASPHALT

RoadSavers

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16. Abstract

In 1995, a project was initiated to assess the costs versus benefits of the Strategic Highway Research Program (SHRP). Information was collected from State and local highway agencies on their experiences with the SHRP products, and this information was used as the basis for an economic analysis of the costs and benefits of the program and its products.

This report summarizes the preliminary findings of an economic analysis conducted by the Texas Transportation Institute. It also describes the hot-mix asphalt technologies developed under SHRP and the experiences of highway agencies that have used them. In addition, it summarizes the objectives of the research conducted under SHRP on asphalt, and outlines the work by the Federal Highway Administration to refine the products and encourage their adoption.

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INTRODUCTION

The 1984 Strategic Transportation Research Study identified asphalt as one of six priority areas for research and development.[1] As a result, asphalt became one of the key areas in the Strategic Highway Research Program (SHRP).[2] Established by Congress in 1987, SHRP had a mission to increase the durability and safety of our Nation's roads and bridges.

Research conducted under SHRP targeted six areas: asphalt, concrete and structures, long-term pavement performance, pavement maintenance, work zone safety, and snow and ice control. One hundred and thirty products, including new specifications, tests, equipment, and reports, resulted from SHRP research contracts, which expired in March 1993.

In 1995, shortly after SHRP concluded and during the early stages of the Federal Highway Administration's (FHWA) national program to encourage implementation of the SHRP products, the Transportation Research Board (TRB) SHRP Committee suggested that an objective assessment of the program and its products be conducted. The study, which was conducted during 1996 and 1997, was launched and funded by FHWA. Overall direction for the study was provided by FHWA with the help of the SHRP Assessment Steering Group. The assessment project was managed by the transportation technology transfer center at the University of Nevada-Reno (UNR). The technology transfer centers in Florida, Indiana, Minnesota, Pennsylvania, and Texas assisted UNR in collecting information on how State and local highway agencies were using SHRP products. This information was turned over to a team of engineers and economists at the Texas Transportation Institute (TTI) for use in an economic analysis of the costs versus benefits of SHRP and the SHRP products.

This report presents the preliminary findings of the economic analysis conducted by TTI. It describes the objectives and accomplishments of the research conducted under SHRP on asphalt, as well as the products developed from that research. It also summarizes how State and local governments are using those products.

Four other summary reports, describing the results of the benefits-versus-costs analysis of SHRP's concrete and structures, pavement maintenance, snow and ice control, and work zone safety products, are also available.[3–6, *]

* The long-term pavement performance (LTPP) program is only at its midpoint, and thus it is too early to report on the economic benefits of its products.

BACKGROUND

The $150 million spent on SHRP over 5 years is the largest single expenditure ever devoted to transportation infrastructure research. Product refinements and implementation continue with the support of FHWA, State highway agencies, and industry.

The Intermodal Surface Transportation Efficiency Act of 1991 authorized an additional $108 million for SHRP implementation and for continuation of the long-term pavement performance (LTPP) program. Funding for SHRP came from a set-aside of one-quarter of 1 percent of Federal-aid highway funds apportioned to the States.

SHRP was administered by the National Research Council in cooperation with FHWA and the American Association of State Highway and Transportation Officials (AASHTO). FHWA has taken the lead in helping State and local highway agencies make effective use of SHRP products.

OBJECTIVE

The objective of the SHRP research was to improve pavement performance by increasing understanding of the chemical and physical properties of asphalt binders and asphalt mixtures.[1]

RESEARCH PROJECTS

The proposed SHRP research on asphalt identified five projects:[2]

1. Asphalt properties.
2. Performance-based testing and measuring systems.
3. Models to predict pavement performance.
4. Performance-based specifications and an asphalt-aggregate mixture analysis system.
5. Project coordination.

The results of these research projects were expected to provide a performance-based asphalt binder specification and an asphalt-aggregate mixture design and analysis system.[2]

ASPHALT RESEARCH

Of the approximately $110 billion spent each year on our Nation's highways, about $15 billion is spent on hot-mix asphalt. Despite this large expenditure on asphalt, coupled with the fact that more than 90 percent of our paved highways are surfaced with the material, relatively little is spent on asphalt research and development.[7]

ACCOMPLISHMENTS

After 5 years of intensive research and testing, SHRP introduced the Superpave system in 1992 to give highway engineers and contractors the tools to design better-performing asphalt mixtures and pavements. FHWA assumed responsibility for further development and validation of the Superpave specifications and test procedures and initiated a national program to encourage the adoption of the Superpave system.

The target date for adoption of the Superpave binder specifications by State departments of transportation is 1997-1998. The target date for adoption of the Superpave volumetric mixture design and analysis system is 2000. The actual date of the States' full adoption of the Superpave system will depend on when the system's development is complete.

The Superpave system consists of three interrelated elements:

1. Asphalt binder specification.
2. Volumetric mix design and analysis system.
3. Mix analysis tests and a performance prediction system that includes computer software, a weather database, and environmental and performance models.

The Superpave system primarily addresses three types of pavement distress:

1. Permanent deformation, which results from inadequate shear strength in the asphalt mix.
2. Fatigue cracking, which results from repeated traffic loads.
3. Low-temperature cracking, which results when an asphalt pavement shrinks as a result of cooling in the pavement and the tensile stress in the pavement exceeds the pavement's tensile strength.

The SHRP asphalt research program was largely directed toward hot-mix asphalt. However, results of the binder and mixture research also have applications for asphalt-bound materials used for routine and preventive maintenance operations. Table 1 lists the products developed under SHRP.

The binder specification uses the dynamic shear rheometer, the bending beam rheometer, and the rotational viscometer to characterize the physical properties of the asphalt binder over an extended temperature range. Short-term and long-term aging systems are used to simulate hardening of the asphalt binder during production and service. Another significant product of the SHRP research is the pressure aging vessel, which is used to simulate long-term (service) aging of an asphalt binder.

The volumetric mix design system uses the Superpave gyratory compactor to simulate the effects of production and traffic on an asphalt mix. The mixture analysis and performance prediction system uses the Superpave shear tester and the indirect tensile tester to predict permanent deformation, fatigue cracking, and thermal cracking of asphalt mixes.

POST-SHRP ACTIVITIES

The SHRP research on asphalt has led to additional research, development, and implementation activities sponsored by FHWA, the National Cooperative Highway Research Program (NCHRP), States, and industry. FHWA activities include projects to improve the mixture analysis and performance prediction models, as well as an extensive effort to encourage implementation of the Superpave system, which started at the conclusion of SHRP and will continue for the next several years. NCHRP projects include research on quality control/quality assurance, gyratory compaction, water sensitivity, and modified binders. State and industry activities include participation in regional asphalt user-producer groups, FHWA technical working groups and expert task groups, and local validation studies.

FHWA Implementation

Equipment Purchases

A pooled fund purchase provided States a means of acquiring a full set of binder test equipment and a Superpave gyratory compactor for volumetric mixture design. In addition, FHWA provided a full set of the binder test equipment to each of the five Superpave regional centers. This equipment will be used for training engineers and technicians and for testing asphalt binder samples provided by State departments of transportation and others.

Mobile Asphalt Laboratories

FHWA has two mobile asphalt laboratories staffed with skilled technicians who provide assistance and training in Superpave technology and quality control/quality assurance at a dozen highway construction sites across the country each year. In 1995, one of the labs was on extended assignment at WesTrack, FHWA's asphalt test track in Reno, Nevada. The mobile laboratories are furnished with the Superpave binder test and mix design equipment, including the Superpave gyratory compactor, which is used to demonstrate the principles of volumetric mix design.

Software

FHWA has contracted with the University of Maryland and a team of subcontractors to refine the Superpave software and performance prediction models. The first version of the software was demonstrated at FHWA's technology fair of SHRP products, which was held in conjunction with the 1996 annual meeting of the Transportation Research Board in Washington, D.C. The refined DOS-based software, version 1.0, was distributed to users in the field. An updated, enhanced Windows 95-based version of the software is scheduled to be completed by the University of Maryland team in 1998.

Field Performance

Currently, the Superpave system is being tested and validated through a variety of experimental projects, including the WesTrack facility. The track features 26 hot-mix asphalt pavement test sections. The performance of the various test sections will be evaluated against the Superpave performance prediction models.

FHWA also is collecting performance data using two accelerated loading facility machines at the Turner-Fairbank Highway Research Center to validate the Superpave asphalt binder and mixture specifications. Full-scale pavement test sections are being constructed and their performance monitored under the LTPP program's specific pavement studies experiment on the Superpave binder specification and mix design system (SPS-9).

Training Programs

Since 1993, the Asphalt Institute, under contract with FHWA, has offered Superpave training courses and technical assistance to State departments of transportation, paving contractors, asphalt suppliers, and others. The institute's National Asphalt Training Center in Lexington, Kentucky, has held sixteen 1-week courses on binder testing for 290 participants. The center has also held fourteen 1-week courses on mix design for 275 engineers and technicians.

FHWA recently awarded the Asphalt Institute a contract for the second phase of Superpave training. Over the next 3 years, the National Asphalt Training Center will provide additional laboratory training in the area of mix design and pavement performance prediction. The center also provides on-site training and technical assistance to State departments of transportation.

Regional Coordination and Training

The asphalt user-producer groups continue to play a key role in developing and implementing the Superpave system. They have played a focal role in outlining a sensible, well-planned strategy for adopting the Superpave system on a regional basis.

The Superpave regional centers were established in the asphalt user-producer group regions. Operated jointly by universities and State departments of transportation, the centers conduct shakedown, ruggedness, precision, and bias testing programs using the Superpave shear tester and indirect tensile tester. FHWA has also used the Superpave regional centers to develop and provide training.

Case Studies

Some State and local transportation departments are using the Superpave binder specification and mixture design system on a limited basis. A survey conducted by the Nevada Technology Transfer (T^2) Center found that implementation of the Superpave system was being undertaken in varying degrees in 18 States. Table 2 contains a State-by-State listing of the case studies that were developed based on the results of the survey and that were used in the economic analysis.*

Although more than 50 pavements had been constructed using the new technology, most of these 18 States were still evaluating the Superpave equipment and specifications. These States had incorporated performance-graded binders into projects on an experimental basis, and were scheduled to fully implement the performance-graded binder specification in the near future.

A few States were also using the Superpave mixture design system on an experimental basis. At the time, it was too early to make an adequate assessment of the benefits of the mix design procedures.

The States reported that Superpave mixtures cost more than previously used conventional mixtures. However, users expected that prices would drop as familiarity with materials increases. In general, respondents to the Nevada T^2 Center survey were very favorable toward the Superpave system. Most respondents expected longer pavement life and lower maintenance costs.

The Superpave system has also been used by industry to develop mixture designs for warranteed projects in California and Indiana. Volumetric mixture design, advanced mixture tests, and performance prediction models were used on these projects.

* FHWA has published 104 RoadSavers case studies, many of which were based on case studies collected for the economic analysis. The RoadSavers case studies are available on the Internet at www.ota.fhwa.dot .gov/roadsvr.

ECONOMIC BENEFITS

Asphalt binders currently used in Georgia, Nevada, and Texas and at the National Center for Asphalt Technology were evaluated for compliance with the Superpave binder specification. It was estimated that approximately 25 percent of the country's paving projects use an asphalt binder that does not meet the Superpave specifications.[8]

The selection of the correct Superpave asphalt binder should increase the life expectancy of a typical hot-mix asphalt overlay from an estimated 8 years to an estimated 12 years. This projection is based on relationships between asphalt binder properties and hot-mix asphalt performance. The analysis did not consider increased pavement performance resulting from the Superpave mixture design procedures.[9]

To determine the cost savings from national implementation of the Superpave binder specification, a more conservative estimate of the improvement in performance life was used. The analysis assumed that fewer than 25 percent of paving projects select the incorrect binder, and that the use of the correct binder will increase the life of an overlay from 8 years to only 10 years, not 12 years.[9]

To predict the potential savings from selecting the correct asphalt binders, nine criteria were established.

1. Data in *Highway Statistics* were used to estimate mileage and average daily traffic by functional class for asphalt pavements.[7]
2. Highway mileage in local functional classes was not used for these calculations.
3. Asphalt pavements with a thickness of 1 in (25 mm) or less were excluded from these calculations.
4. Estimates for the cost of asphalt overlays were obtained from FHWA's Highway Performance Monitoring System. A figure of approximately $60,000 per lane-mile ($37,000 per lane-kilometer) was used for asphalt overlays with current binders, and a figure of $64,000 per lane-mile ($40,000 per lane-kilometer) was used for asphalt overlays with the new Superpave binder (6.7 percent increase in cost).
5. User benefits from the Superpave system were derived from reductions in delay costs associated with fewer overlays and repairs needed during the life of the pavement, and from reductions in vehicle operating costs because of smoother pavements.
6. Relationships between pavement roughness (Present Serviceability Index), age, and vehicle operating costs based on reduced vehicle speed, increased fuel consumption, and increased wear on vehicles were developed from MicroBENCOST data.[10]
7. A 40-year analysis was used for life-cycle costs, with a 5 percent discount rate.
8. An annual traffic growth rate of 2.1 percent was used over the analysis period.[9]
9. Implementation costs for equipment purchases and maintenance and for additional personnel were subtracted from the estimated cost savings associated with increases in performance life.[9]

Based on these criteria, if the Superpave binder specification was immediately implemented, the potential annual savings would be about $750 million in public highway agency costs and about $2 billion in user costs, for a total of $2.8 billion (Table 3).

Superpave technology will, however, not be immediately implemented by all highway departments. Taking the maximum annual savings of $2.8 billion, savings for slow, moderate, and fast implementation scenarios were calculated using a 5 percent discount rate (Tables 4, 5, and 6).

Slow Implementation

- Implementation reaches 100 percent after 10 years.
- Estimated public highway agency savings: $6 billion.
- Estimated user savings: $16.5 billion.
- Estimated public highway agency and user savings: $22.5 billion.

Moderate Implementation

- Implementation reaches 100 percent after 5 years.
- Estimated public highway agency savings: $7.9 billion.
- Estimated user savings: $21.7 billion.
- Estimated public highway agency and user savings: $29.6 billion.

Fast Implementation

- Implementation reaches 100 percent after 1 year.
- Estimated public highway agency savings: $9.8 billion.
- Estimated user savings: $26.7 billion.
- Estimated public highway agency and user savings: $36.5 billion.

The cost of SHRP-related asphalt research, development, and implementation was estimated at $230 million over 20 years.[9] Based on the implementation scenarios given above, benefit-cost ratios are expected to range from 26 to 43 for public highway agencies and to range from 72 to 116 for users, depending on the rate of implementation of the Superpave binder specification (Table 7).

The benefit-cost ratios mean that for each dollar spent on research, development, and implementation, public highway agencies can expect a return of $26 at a slow implementation rate, $34 at a moderate implementation rate and $43 at a fast implementation rate. User benefits are expected to be $72, $94 and $116. Combined public highway agency and user benefits are expected to range from $98 to $159 (Table 7).

SUMMARY

Asphalt pavements that are designed to last longer will require less time and money for repairs. The Superpave system developed under SHRP is expected to produce pavements that hold up well under the stresses of extreme weather conditions and heavy traffic loads. The result is a more durable asphalt pavement at significant cost savings for taxpayers.

The Superpave volumetric mix design system is scheduled for adoption nationwide by 2000. Switching to the new system is a large task that requires a well-planned and coordinated effort by all partners in the highway industry. FHWA and States have initiated a national program involving user-producer groups to develop sensible strategies for the implementation of the Superpave system.

Benefit-cost ratios will increase substantially with implementation of the Superpave technology as it is finalized by FHWA.

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Table 1. SHRP Asphalt Products

Product Area	Product Number and Title	
Asphalt Binder	1001	Binder Specification
	1002	Bending Beam Rheometer
	1004	Asphalt Extraction and Recovery
	1005	Low Temperature Direct Tension Test
	1006	High Temperature Viscosity Test
	1007	Dynamic Shear Rheometer
	1009	Binder Chromatography
	1010	Refiner's Guide
	1025	Short Term Aging
	1030	Long Term Aging
Volumetric Mix Design	1011	Mix Specification
	1014	Gyratory Compactor and Method
	1026	Modified Rice Correction Test
Mixture Analysis and Performance Prediction	1012	Superpave Mix Design System
	1013	Net Absorption Test
	1015	Rolling Steel Wheel Compaction Method
	1017	Shear Test and Device
	1019	Flexural Fatigue Life Test
	1021	Thermal Stress Restrained Specimen Test
	1022	Indirect Tensile Creep and Failure Test
	1024	Environmental Conditioning System

Table 2. Asphalt Case Studies

State	Case Study Title
Alabama	A Smoother Ride on Superpave
Arizona	New Asphalt Pavement Mix Outlasts Desert Heat
Colorado	New Asphalt Technology Assures Skiers and Truckers of a Smooth Ride into the Mountains
Connecticut	Connecticut Puts Superpave System to the Test
Delaware	A Better Road to the Beach
Louisiana	New Test Device is a Real “Workhorse”
Minnesota	County Leads the Way With Innovating Pavement Design System
Missouri	New Asphalt Technology Improves Durability
Nebraska	Better Compaction in the Lab Leads to Improved Asphalt Mixes
New Mexico	States Team Up to Buy Equipment to Design Longer-Lasting Roads
New York	New York Adopts Superpave System for Crack-Free Pavements
North Dakota	More Durable Roads Ahead for North Dakota
Ohio	Using Superpave to Prevent Cracking
Pennsylvania	Superpave System Beefs Up Intersections in Allentown
	Pennsylvania Turns to Superpave Pavements
Texas	New Pavement Technology Promises Texas-Sized Savings
Vermont	Vermont Takes First Steps on the Road to Longer Pavements
Virginia	New Pavement System Great for Trouble Spots
Wisconsin	Better Materials Mean Better Pavements
	Innovative Asphalt Pavement Technology Key to Better Roads

Table 3. Total Annual Cost Savings (Million $)

	Urban			Rural			
	Freeway	4-Lane Divided	2-Lane Undivided	Freeway	4-Lane Divided	2-Lane Undivided	Total
Agency Cost Savings							
Subtotal	50.60	108.96	173.09	51.74	28.47	334.87	747.73
Motorist Cost Savings							
Delay	57.35	138.28	289.58	28.85	18.35	167.12	699.53
VOC*	195.08	352.20	293.43	128.72	50.93	323.57	1,343.93
Subtotal	252.43	490.48	583.01	157.57	69.28	490.69	2,043.46
Total Cost Savings	303.03	599.44	756.10	209.31	97.75	825.56	2,791.19

* VOC: Volatile organic compounds.

Table 4. Total Asphalt Cost Savings with a Slow Implementation Scenario

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million $)	Discounted Motorist Savings (Million $)	Total Discounted Savings (Million $)
1	2.4	17.95	49.04	66.99
2	6.8	48.42	132.34	180.76
3	13.3	90.20	246.51	336.71
4	21.4	138.23	377.76	515.99
5	31.0	190.70	521.16	711.86
6	42.2	247.24	675.66	922.90
7	54.7	305.21	834.10	1,139.31
8	68.6	364.54	996.24	1,360.78
9	83.7	423.60	1,157.65	1,581.25
10	100.0	481.99	1,317.23	1,799.22
11	100.0	459.04	1,254.51	1,713.55
12	100.0	437.18	1,194.77	1,631.95
13	100.0	416.37	1,137.87	1,554.24
14	100.0	396.54	1,083.69	1,480.23
15	100.0	377.66	1,032.08	1,409.74
16	100.0	359.67	982.94	1,342.61
17	100.0	342.54	936.13	1,278.67
18	100.0	326.23	891.55	1,217.78
19	100.0	310.70	849.10	1,159.80
20	100.0	295.90	808.67	1,104.57
20-Year Total		6,029.91	16,479.00	22,508.91
Equiv. Ann. Total		483.86	1,322.32	1,806.18

Table 5. Total Asphalt Cost Savings with a Moderate Implementation Scenario

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million $)	Discounted Motorist Savings (Million $)	Total Discounted Savings (Million $)
1	6.8	50.85	138.96	189.80
2	21.4	152.39	416.48	568.87
3	42.2	286.21	782.17	1,068.37
4	68.6	443.10	1,210.94	1,654.04
5	100.0	615.16	1,681.16	2,296.32
6	100.0	585.87	1,601.10	2,186.97
7	100.0	557.97	1,524.86	2,082.83
8	100.0	531.40	1,452.25	1,983.65
9	100.0	506.09	1,383.09	1,889.19
10	100.0	481.99	1,317.23	1,799.22
11	100.0	459.04	1,254.51	1,713.55
12	100.0	437.18	1,194.77	1,631.95
13	100.0	416.37	1,137.87	1,554.24
14	100.0	396.54	1,083.69	1,480.23
15	100.0	377.66	1,032.08	1,409.74
16	100.0	359.67	982.94	1,342.61
17	100.0	342.54	936.13	1,278.68
18	100.0	326.23	891.55	1,217.79
19	100.0	310.70	849.10	1,159.80
20	100.0	295.90	808.67	1,104.57
20-Year Total		7,932.87	21,679.52	29,612.39
Equiv. Ann. Total		636.55	1,739.62	2,376.18

Table 6. Total Asphalt Cost Savings with a Fast Implementation Scenario

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million $)	Discounted Motorist Savings (Million $)	Total Discounted Savings (Million $)
1	100.0	747.73	2,043.46	2,791.19
2	100.0	712.13	1,946.15	2,658.28
3	100.0	678.21	1,853.48	2,531.69
4	100.0	645.92	1,765.21	2,411.13
5	100.0	615.16	1,681.16	2,296.32
6	100.0	585.87	1,601.10	2,186.97
7	100.0	557.97	1,524.86	2,082.83
8	100.0	531.40	1,452.25	1,983.65
9	100.0	506.09	1,383.09	1,889.18
10	100.0	481.99	1,317.23	1,799.22
11	100.0	459.04	1,254.51	1,713.55
12	100.0	437.18	1,194.77	1,631.95
13	100.0	416.37	1,137.87	1,554.24
14	100.0	396.54	1,083.69	1,480.23
15	100.0	377.66	1,032.08	1,409.74
16	100.0	359.67	982.94	1,342.61
17	100.0	342.54	936.13	1,278.67
18	100.0	326.23	891.55	1,217.78
19	100.0	310.70	849.10	1,159.80
20	100.0	295.90	808.67	1,104.57
20-Year Total		9,784.30	26,739.30	36,523.60
Equiv. Ann. Total		785.12	2,145.63	2,930.75

Table 7. Twenty-Year Cost-Benefit Ratio* and Cost Savings (Billion $) for SHRP Asphalt Research

	Implementation Rate					
	Slow		Moderate		Fast	
	Ratio†	Savings (Billion $)	Ratio†	Savings (Billion $)	Ratio†	Savings (Billion $)
Agency Savings	26	6.0	34	7.9	43	9.8
User Savings	72	16.5	94	21.7	116	26.7
Agency Plus User Savings	98	22.5	129	29.6	159	36.5

* Based on an estimated 20-year research, development, and implementation cost of $230 million.

† Totals may not add up because of rounding.

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